Wall interference studies — Revisited

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Abstract: A brief review is made of the methods currently available for assessing and correcting the data for effects due to wall interference. Computational simulation of ventilated walls has been described. The DLR panel code available in the division is being modified to handle flow past a model with sting and support strut in a wind tunnel whose walls could be either solid, or, ventilated, or, open-jet. The effect of sting, strut, and walls on the model data is under study.

1. Introduction

It is obvious that the flow past wind tunnel model is not the same as that past a full-scale vehicle moving in free air. Hence the data from the conventional wind tunnels have to be corrected. These corrections depend on the type of the wall and the size of the model in relation to cross section of the tunnel (blockage ratio). These corrections to the data from a ventilated-wall tunnel were never applied as it was felt that the 'cure might be worse than the disease.' If the model blockage ratio is < 0.5%, then no corrections need be applied. However, if this limit is exceeded, there is a need to assess, and possibly correct, the data for wall interference effects.

Till recently, the theoretical methods for obtaining corrections depended on linear theories. The more recent methods use the measured wall pressures in conjunction with CFD tools. Alternately, models could be tested in the so called 'adaptive-wall facilities' to obtain interference-free data. There are no adaptive-wall testing facilities in India and as such it is important to develop techniques to assess and correct the data for the wall interference.

2. A review of methods

The methods for"studying wall-interference can be classified into two categories - classical and current.

2.1. The classical approach

In the classical approach, the model is replaced by singularities and the wall by a set of images. The wall effects result in an effective change of circulation and speed of the flow over the model. These are known as lift and blockage effects, respectively.

The lift interference is due to the change in the circulation or vorticity around the model. The presence of the wall results in an effective streamline curvature effect due to axial variation of upwash over the model and changes the downwash. The solid or wake blockage is due to the volume of the model and its wake and is expressed as a change in the longitudinal velocity component. The corrections by the classical method are tabulated in Vayssaire (1973).

Ventilated walls have either longitudinal slots or perforations (Fig. 1 schematically illustrates the concept of slotted walls). Earlier studies assumed that the real wall could be replaced by an equivalent homogeneous boundary having a similiar influence as that of a real wall In order to compute the corrections it would be necessary to know the porosity of the wall Determining this directly by measuring the pressure differential across the wall and the flow through the wall is very difficult and uncertain.

2.2. The current approach

The current approach makes use of CFD tools. These tools require the pressure distribution on a control surface surrounding the model. The methods due to Capelier *et al.* (1978), Sawada (1980), Mokry (1982), and Ashill and Weeks (1982) are examples of the current approach and are based on the pressure measured near or at the walls. Of these methods, the one due to Mokry (1982) has been coded and validated by Gopinath (1983). A comprehensive survey of the work done at NAL in the area of wall inteference has been reported by Gopinath (1990).

3. Computational simulation of ventilated walls

Unfortunately, there is no database on wall interference which could be used for validating the codes, particularly in 3-D. For validation of CFD codes used in wall interference studies, the data should be obtained from a tunnel where interference is present, and should be of sufficient amplitude. The model should be instrumented for lifting surface pressures, and forces, and moments. The database should also include 'interference-free' reference data for verification of corrections. Further, the Reynolds number sensitivity should be well defined in order to separate the Reynolds number and the wall interference effects. Otherwise, the discrepancies between the data from different sources may be ascribed to the wrong sources. It must also be noted here that the effect of the tunnel walls on the model is highly model-dependent, and must be evaluated for each model tested (Whoric and Hobbs 1987).

A series of experiments were conducted in the 0.3 m tunnel at NAL, In these experiments the open-area ratios (OAR's) of the slotted top and bottom walls of the test section were varied between 2 and 13%. The dramatic effect of the open-area ratio on the C_p distribution on a BGK airfoil at MOO = 0.782 and $a = 2°$ is brought out in Fig. 2.

It was very tempting to try and simulate these results using a transonic full-potential code. Hence a code has been developed which simulates the flow over airfoils in a wind tunnel (Gopinath *et al.* 1991). A variety of wall characteristics may be modelled through the implementation of appropriate homogeneous wall boundary conditions at the outer boundary in the two-dimensional, transonic full-potential solver.

4. Results and discussion

The flow past a BGK airfoil was computed using the extended version of the full-potential code for open-area ratios varying from 2 to 8 %. The corresponding porosity parameters were arrived at by numerical experimentation. The comparison of theoretically predicted OP distribution on the airfoil with experimental data for three OAR's ($\sigma = 2$, 3, and 8%) are shown in Fig. 3.

Preliminary numerical results clearly bring out, qualitatively, the features displayed b NAL tunnel on a BGK airfoil..

5. Future directions

The flow past the LCA model in a wind tunnel is being analysed by a panel code available in the division, which was modified to handle tunnel wall boundary conditions (Narayana *et al.* 1993). The connecting sting and the support strut have also been panelled, besides the test article (Fig. 4). To start with, the 'all-solid wall' configuration is being tried out This approach in comparison with the Euler code, should be significantly faster for comparable accuracy. Extension to the 'perforated wall' case is on the anvil.

6. Conclusions

It is possible to correct the data for effects due to wall interference from a) either the classical theory, or, b) from pressure signatures on a control surface, with or without the model representation.

The full-potential code developed could be used to simulate ventilated walls and the panel code could be used to assess the corrections due to wall interference, sting and support strut in the subsonic range.

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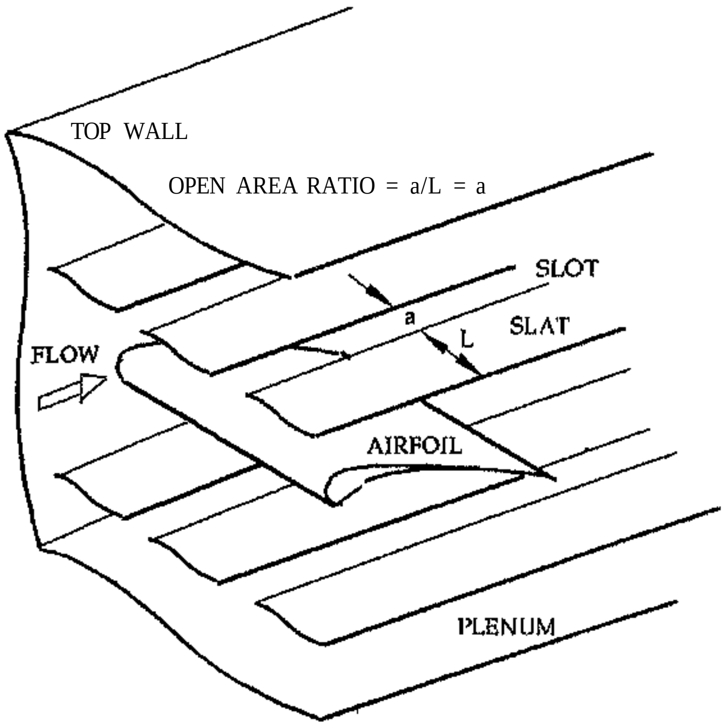


Figure 1. Schematic diagram of a wind tunnel test section with ventilated walls.

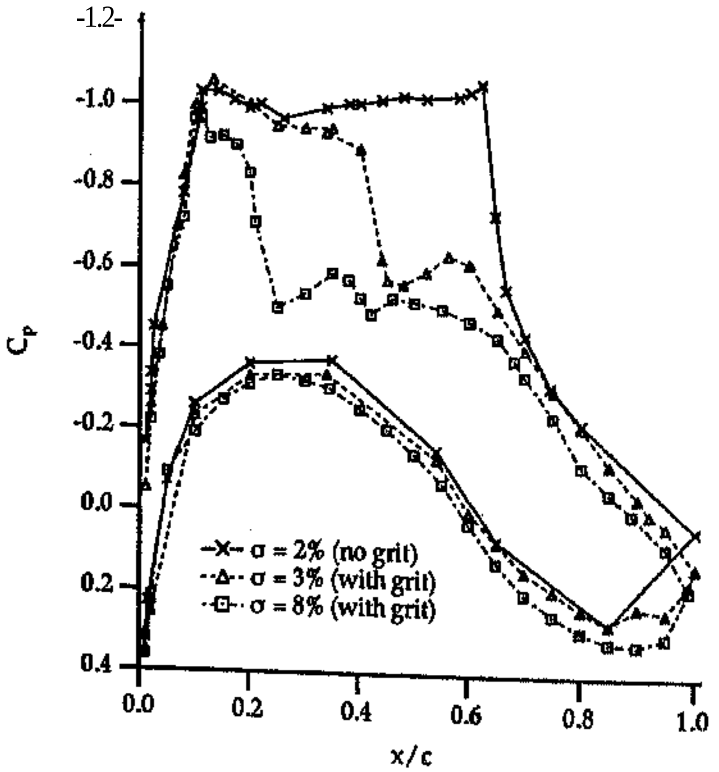
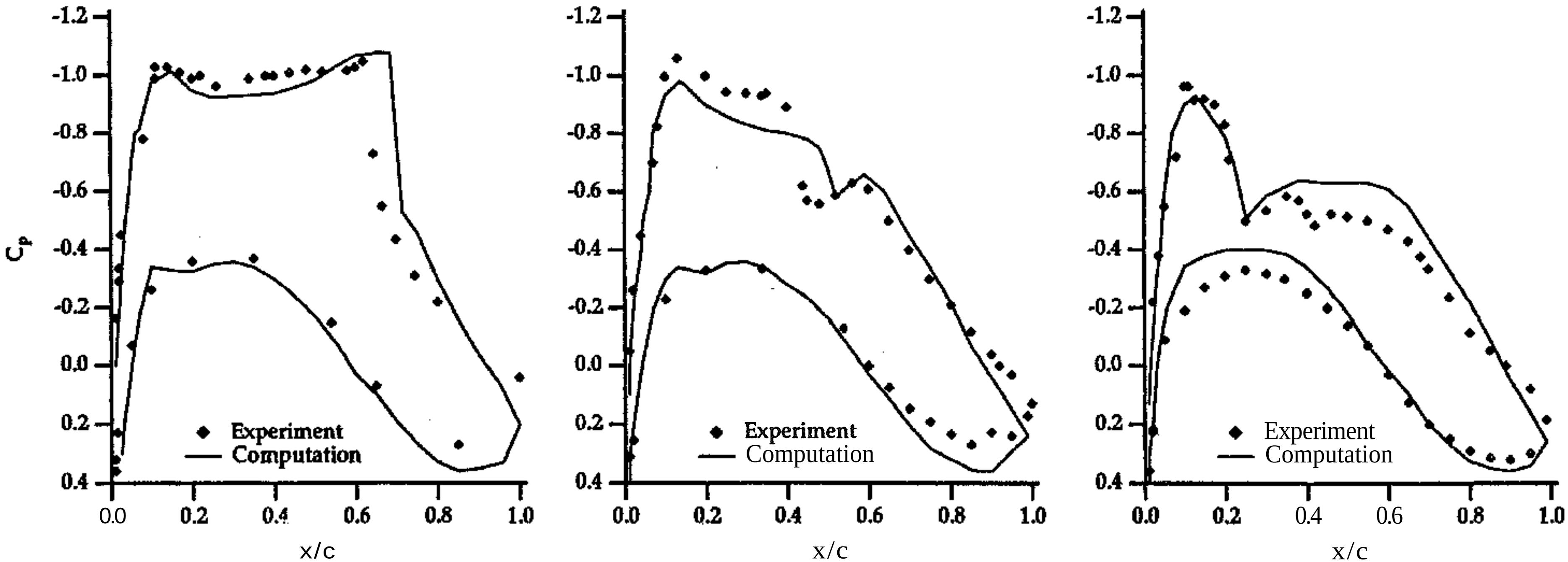


Figure 2. Effect of open-area ratio on the measured pressure distribution around a BGK airfoil at $M_\infty = 0.782$ and $\alpha = 2°$. The experimental results have been obtained from the 0.3 *m* tunnel at NAL.



(a) Open-area ratio (a) = 2%

(b) Open-area ratio (σ) = 3%

(c) Open-area ratio (a) = 8%

Figure 3. Effect of open-area ratio (σ) on the computed pressure distribution over a BGK airfoil. The computed results were obtained using a full-potential code with ventilated-wall boundary conditions.

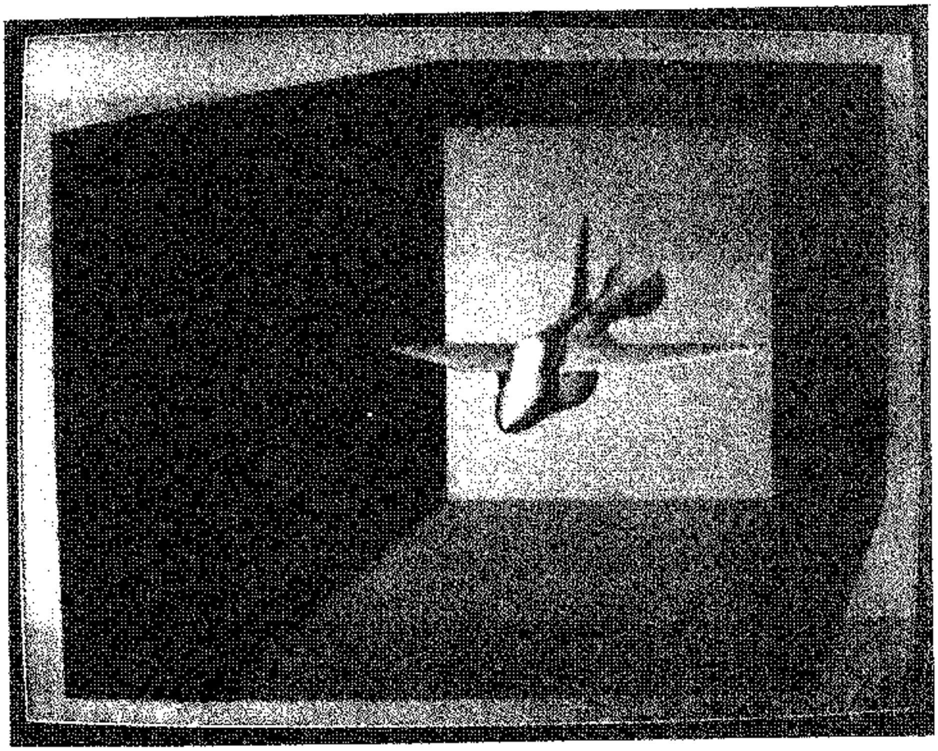


Figure 4. Model of a sting-mounted aircraft placed inside a wind tunnel test section. The model-wall configuration will be used in the assessment of interference effects. (Courtesy: Dr. C. L. Narayana).